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Author(s): Berger, Brian Lee
Chavarria, Rene
Pierce, Stanley W.

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Examination of Intergranular Crack on SC0234

Brian Berger, AMPP-1
Rene Chavarria, AMPP-1
Stanley W. Pierce, AMPP-1

Background

The microstructure of the SC0234 weld was evaluated per DA-SPEC-01067, *General Purpose Heat Source (GPHS) Plutonium-238 Dioxide Fueled Clad Product Specification* and it was determined that the weld microstructure conformed to the quality requirements. During the examination of weld cross section, the metallographic analysis revealed the presence of a surface crack. Prior visual examination per RPS-TA55-303 had not revealed the crack, nor did the surface photography performed per RPS-TA55-302. The presence of the crack does not violate any of the product specifications called out on DA-SPEC-01067. Although there is a well-documented history of weld hot crack susceptibility in the early development of the DOP-26 iridium alloy, a surface crack such as this had not been documented during welding at Los Alamos. In the interest of better understanding the cause; the product engineer/program recommended further examination of the crack.

This report discusses the examination of the crack found in the weld cross section of simulant clad SC0234. Metallography, Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy techniques (EDS) were used in the analysis of the crack and the surrounding weld microstructure.

Sample Preparation

Sample preparation for metallography and SEM/EDS examination was performed by AMPP-1 in accordance with procedures RPS-TA55-302. Two cross sections (0-degrees and 180-degrees) were prepared for metallographic analysis. The 0-degree cross section displaying the crack was subjected to further analysis with SEM/EDS techniques.

Weld cross section samples at 0-degrees and 180-degrees were removed from the GPHS using a slow speed water cooled diamond saw. Following the sectioning and mounting of the simulant clad cross sections, the samples were ground using the following schedule: 100 grit/mesh metal-bonded diamond disc, followed by grinding with silicon carbide paper at 320, 400, 600, 800, and 1200 grit, and then polishing on a vibratory polisher using a 1-micron alumina powder. The sample was cleaned after each grinding step, and after polishing. Sample etching used a 1:1 HCl/H₂O solution with an AC current applied and controlled by a potential of 5 volts for six minutes.

Examination and Observations

Metallographic examination of the weld cross sections revealed the microstructure to be typical of GPHS welds with the exception of an intergranular fracture in the 0-degree weld cross section (Figure 1, Figure 2). The crack occurred in the final portion of the weld, at the vent location prior to the weld start. The crack begins on the weld surface, 1014 microns to the left of the weld centerline, extends into the weld for 420 microns, and terminates 108 microns to the left of the weld centerline.

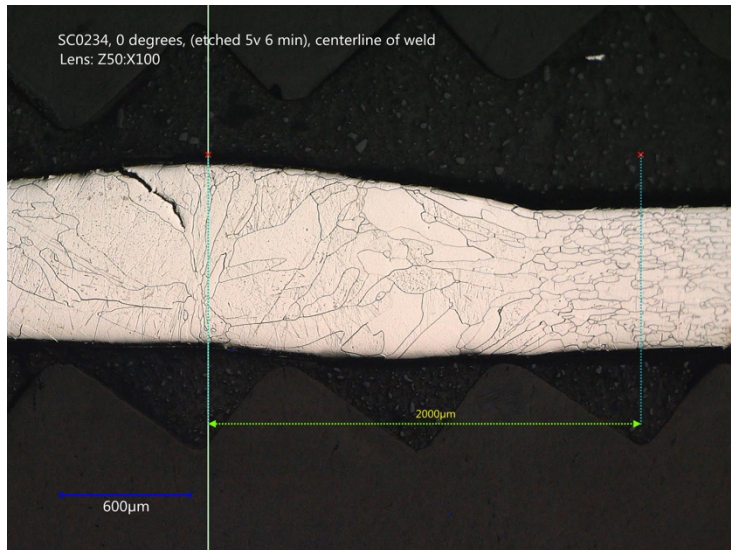


Figure 1 Weld cross section at 0 degrees showing evidence of crack

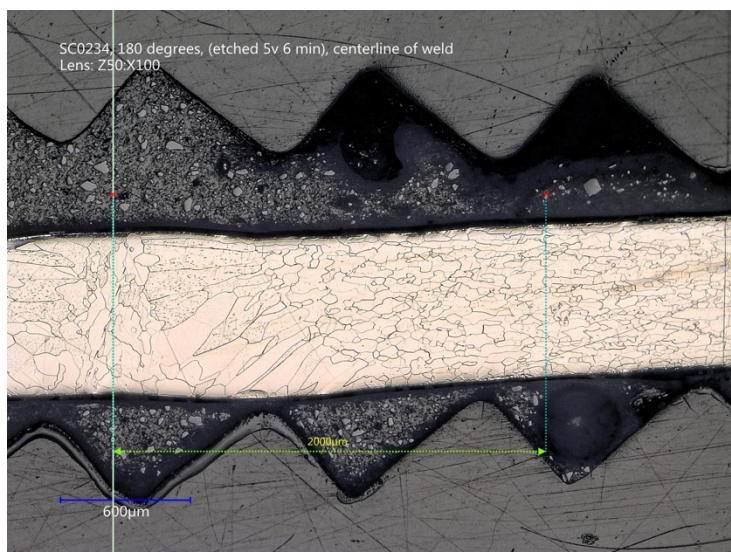


Figure 2 Weld cross section at 180 degrees

Secondary electron imaging confirmed that the crack propagated along the grain boundary and terminated at a grain triple point (Figure 3). The crack tip is blunt and it is preceded by a series of voids in the remnant of what was a liquid film along the grain boundary (Figure 4). This type of crack is known as a solidification crack and it occurs due to thermal tensile stress and reduced grain boundary strength and the presence of a liquid film during final solidification and grain formation. DOP-26 is known to exhibit the formation of a low melting temperature, grain boundary thorium/iridium eutectic that contributes to this type of cracking.

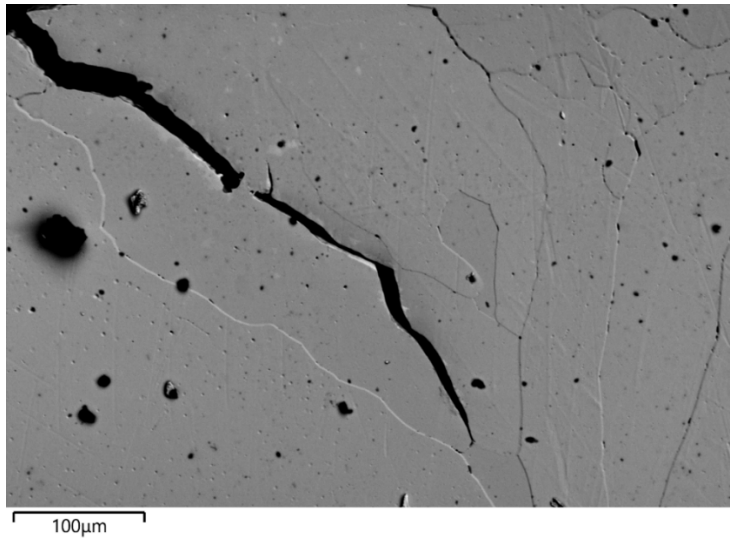


Figure 3 Secondary electron image of crack.

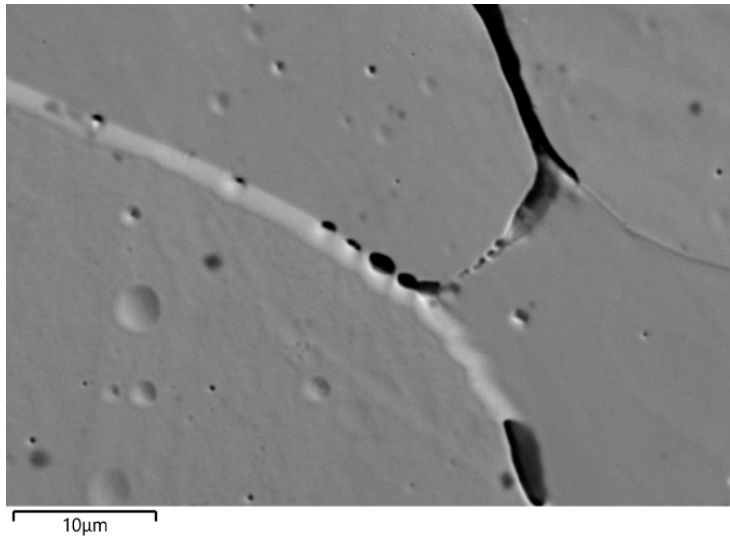


Figure 4 Crack front showing pores.

An additional crack of much smaller size was identified by the SEM (Figure 5). The crack is also intergranular but in comparison to the larger crack it is only 50 microns in length. The crack also terminates at a grain triple point and is preceded by voids. This crack was not discovered during the metallography examination due to it being located near the samples edge and the limited depth of field of optical microscopes. As with the larger crack this fracture appears to be consistent with solidification cracking.

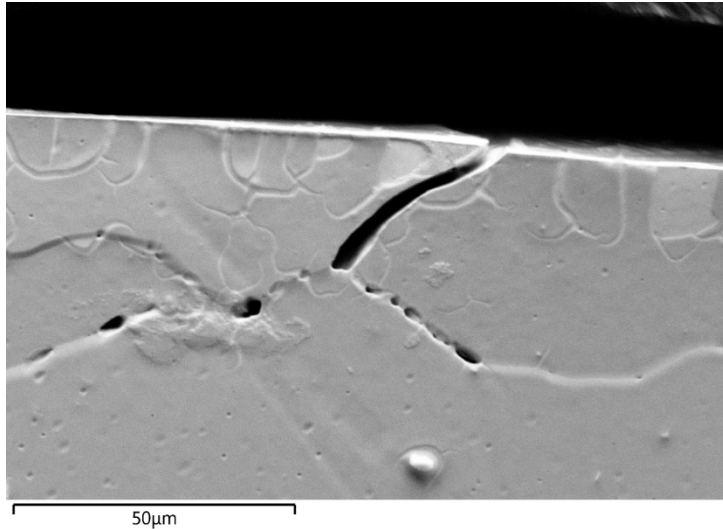


Figure 5 Small crack with pores on grain boundary.

Although the thorium/iridium eutectic is known to be associated with this type of cracking in the DOP-26 alloy, EDS analysis did not identify any secondary phases or abnormal concentrations of thorium or contaminants along the grain boundaries despite the presence of liquid film at the grain boundary. There is no clear reason for this anomalous crack in an otherwise normal weld after many years and several hundred successful welds. The crack is the result of the alloy composition and weld stress. A slightly high or localized concentration of thorium could be a contributor. In addition to the normal weld thermal stress, there may be additional variable stress in the area of the vent due to internal pressurization of the clad as the vent is sealed.

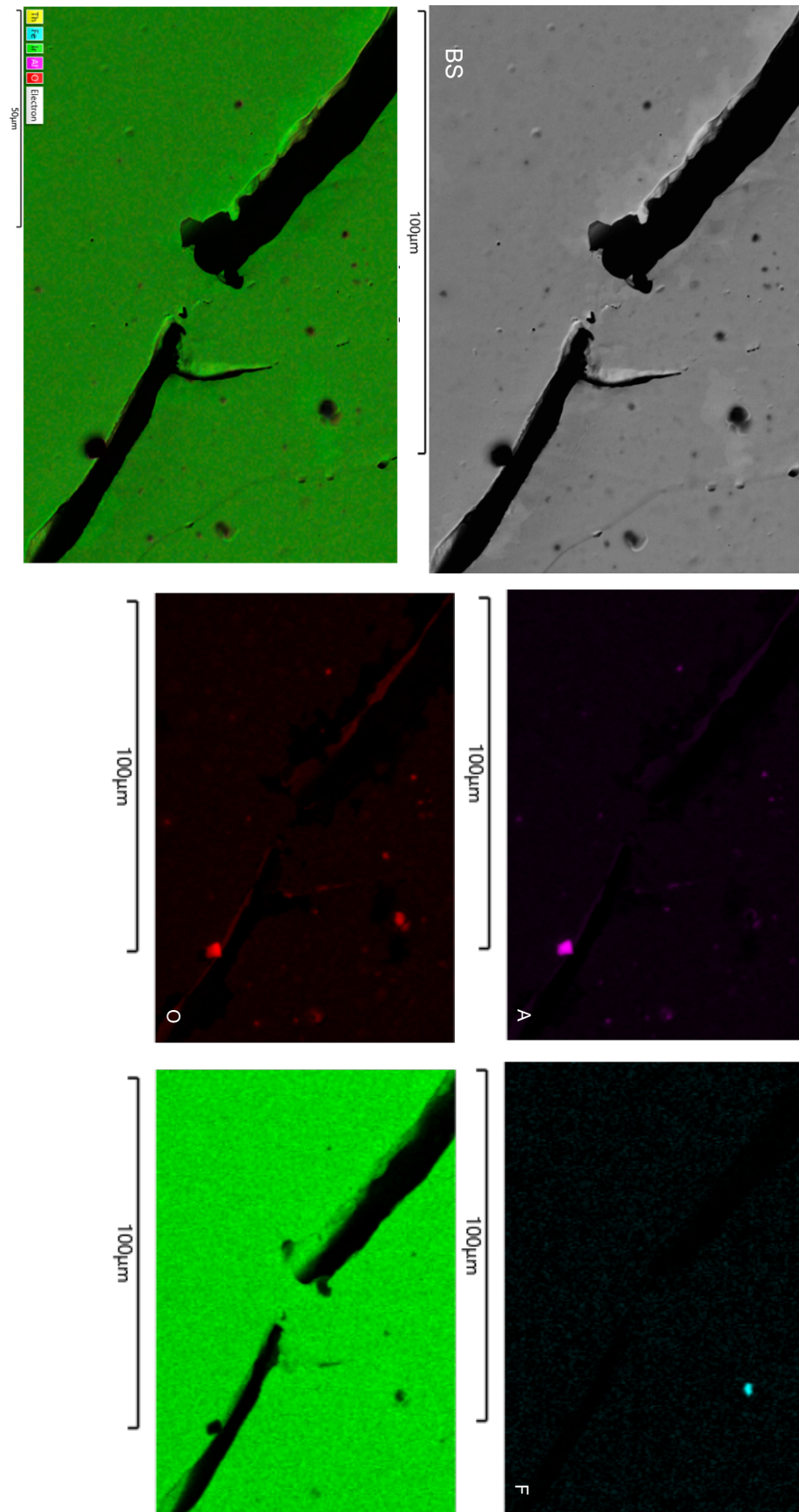


Figure 6 EDS analysis of material surrounding the large crack.